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WASTES INTO PRODUCTION

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MINERAL FIBER PRODUCTION BASED ON ASH FROM THE REPUBLIC OF KAZAKHSTAN USING LOW-TEMPERATURE PLASMA APPARATUS

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A technology for recycling ash-slag wastes in the Republic of Kazakhstan in the production of mineral fibers using an electric plasma apparatus to melt silicate-containing materials and processing the melt into mineral fibers has been developed. The electric plasma apparatus, raw materials and mineral fibers obtained on their basis are studied.

Key words: GRÉS ash, recycling of wastes, electric plasma apparatus, silicate melt, mineral fibers.

The main consumer of primary energy resources in Kazakhstan is the electricity and heat production sector (accounting for about 50% of total fuel consumption). The total electrical capacity of district heating plants (DHP) exceeds 18×10^3 MW. Thermal electric power plants comprise the base of the generating capacities — 87%, hydroelectric power plants contribute 12% and other types of plants 1%. Combined heat and power plants contribute about 38% of the total generating capacity (6.7×10^3 MW). The main fuel resource in Kazakhstan is coal, mainly from the Ékibastuzskoe and Karagandinskoe deposits. These plants consume large amounts of fossil fuel in different forms and other natural resources, converting them into useful energy. These enterprises produce diverse wastes, and as a result large quantities of pollutants enter the environment. In Kazakhstan there are 32 CHPs burning solid fuel, whose combustion results in the formation of ash and slag. The ash and slag comprise a complex system, whose properties depend on the type and combustion regime of the fuel, the design of the heating plant and many other factors.

One way to recycle wastes of this kind is to reprocess them into mineral fiber [1 – 6]. However, the melting temperature of such materials reaches 1700 – 1800°C. This makes it impossible to obtain melt for the production of mineral fiber using conventional technologies. In view of the low temperatures obtained by means of existing melting equipment it is necessary to use low-temperature plasma, which possesses high energy density and temperature 3000 – 5000°C.

An agreement was established between the Karaganda State Technical University (Republic of Kazakhstan) and Tomsk State University of Architecture and Civil Engineering to collaborate on the development of a technology for obtaining high-temperature silicate melts from ash – slag wastes in the Republic of Kazakhstan and to determine the possibility of forming mineral fibers by means of low-temperature plasma.

High-enthalpy plasma flows make it possible to minimize the time from the formation of a homogeneous melt to fiber formation. Actually, the melting processes are combined with fiber formation, giving the melt a high temperature at the moment of fiber formation, which makes it possible to melt batch with high acidity modulus M_a.

Ash from the Karaganda GRÉS-2 [State District Power Plant in Temirtau] and from the district heating plant (DHP) in Kokshetau were used as the starting materials for obtaining mineral fibers. Chemical analysis of ash – slag wastes and, for comparison, basalt (Table 1) showed that the materials studied are characterized by SiO_2 (the main glass former) content adequate for obtaining silicate melt and high content of Al_2O_3, which increases the melting temperature of the raw materials. All this shows that the ash – slag wastes are suitable for obtaining aluminum-silicate melts and can be used in the production of chemically stable mineral fibers.

According to the data in Table 1, because DHP ash has a high content of calcium and magnesium oxides its acidity

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TABLE 1. Average Chemical Composition of the Materials Studied

Raw materials	Content, wt.%						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other	M_a^*
Basalt	48.20	11.80	4.12	13.30	9.15	13.43	2.67
Ash from GRÉS-2	46.76	26.23	7.30	7.70	3.10	16.61	4.87
Ash from DHP	52.30	25.70	5.30	1.50	0.40	14.80	11.47

* Acidity modulus $M_a = \dfrac{SiO_2 + Al_2O_3}{CaO + MgO}$.

modulus M_a is more than twice that of GRÉS-2 ash. The next step in the investigation was to analyze the raw materials in the system $CaO–Al_2O_3–SiO_2$. To determine the figurative points the compositions of the raw mixtures were converted to a three-component system using the conversion constants given in [7]. The results are presented in Table 2.

GRÉS-2 ash melts completely at temperature 1650°C and DHP ash at 1750°C. The amount of the primary liquid phase is 20% for GRÉS-2 ash and 10% for DHP ash (Fig. 1).

Analysis of the melting curves suggests that the complexity of the melting of the materials studied increases from GRÉS-2 to DHP ash, which experimental studies confirm. The more fluid the melt, the more quickly it forms. According to [8], at high Al_2O_3 concentration the liquid phase is already present at 1350°C. The ash is characterized by a relatively small amount of primary melt (10 – 20%). For the wastes studied, chemically uniform melt suitable for the production of mineral fiber and other construction materials obtains in the range 1350 – 1750°C.

An electric plasma apparatus was developed to obtain melt from such components (Fig. 2). It consists of the following basic units: dc power source *9*; plasma reactor *1*; graphite anode *2*; setup for dispensing the disperse material; and, rotating reactor *8*.

A setup for obtaining silicate melts was developed previously [9], but because the melting and fiber production processes had to be implemented in a single stage it was modernized by replacing the melting furnace with a rotating reactor and adding a hollow cylindrical graphite anode with the starting material being fed along the inner walls of the cylinder.

The principle of operation of the setup is based on the interaction of highly concentrated plasma flows *4* with the powdered refractory silicate-containing material *5* (GRÉS

TABLE 2. Ratio of the Oxides in the Starting Materials after Conversion to a Three-Component System $CaO–Al_2O_3–SiO_2$

Ash	Mass fraction, %		
	CaO	Al_2O_3	SiO_2
GRÉS-2	13.30	35.36	51.34
DHP	2.84	35.78	61.38

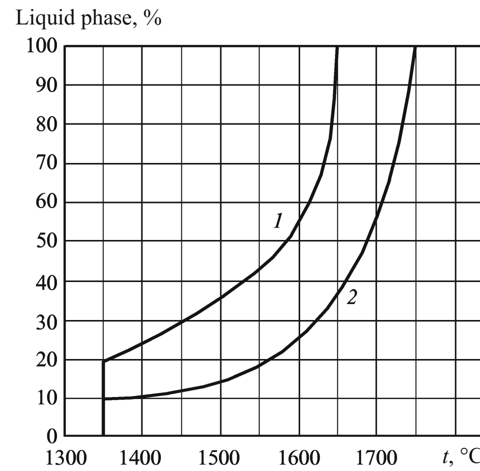

Fig. 1. Liquid phase content in the raw materials versus temperature: *1*) GRÉS-2 ash; *2*) DHP ash.

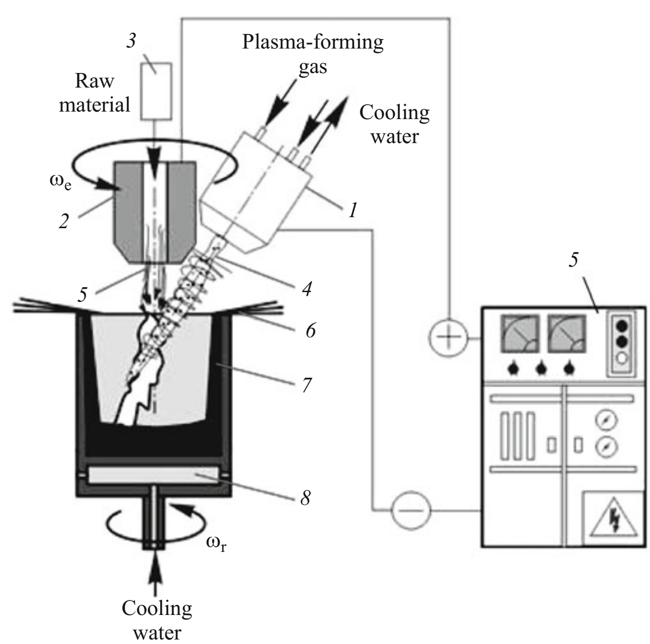

Fig. 2. Arrangement of the electric plasma apparatus for obtaining mineral fibers: *1*) plasmatron; *2*) graphite anode; *3*) dispensing setup; *4*) plasma arc; *5*) raw material; *6*) mineral fibers; *7*) trimming layer; *8*) rotating reactor; *9*) dc power source.

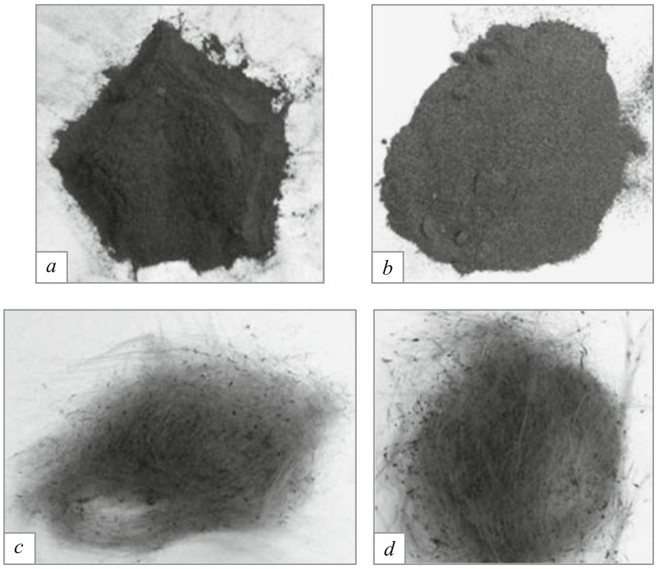

Fig. 3. Photographs of the experimental materials and fibers obtained: *a*) GRÉS-2 ash; *b*) mineral fiber based on GRÉS-2 ash; *c*) DHP ash; *d*) mineral fiber based on DHP ash.

and DHP ash). As a result a melt of disperse particles is produced, which is followed by the formation of mineral fibers *6*. The melt enters the rotating reactor *8*, where under the action of centrifugal forces it ascends along the walls of the reactor and, detaching from its edges, stretches into fibers, which enter the cooling chamber. During the operation of the plasmatron the melted particles settle on the wall of the rotating cylinder *8* and form a trimming layer *7* with low thermal conductivity, which protects the walls of the reactor.

In the course of the investigations of the production of mineral fibers the productivity and capacity of the experimental setup were determined.

Technical Characteristics of the Experimental Setup

Dispenser capacity, kg/h	15.6
Reactor rotation rate, min^{-1}	4200.0
Current, A	240.0
Voltage, V	150.0
Power, kW	36.0

The fiber capacity of the electric plasma setup was 10.8 kg/h. In addition, it can be concluded that the power of the low-temperature plasma generator is adequate to obtain 100% melt of the starting raw material in short times and forming it into mineral fibers (Fig. 3). The properties of the experimental fiber (Table 3) obtained meet the technical specifications for mineral wool [10].

These studies established that in the Republic of Kazakhstan GRÉS-2 and RK-2 ash can be used to obtain chemically stable mineral fiber by means of low-temperature plasma. The mineral fiber produced in this way is characterized by high performance as well as enhanced resistance to high temperatures.

TABLE 3. Properties of Mineral Fibers

Properties	Mineral fiber from GRÉS-2	Mineral fiber from DHP ash	Mineral fiber from basalt
Acidity modulus	< 4.63	< 11.28	< 1.6
Water resistance pH, at most	7	9	4
Average fiber diameter, μm, at most	11	14	6
Shot content, %	18	25	12
Fiber length, mm	50 – 90	60 – 90	40 – 60
Thermal conductivity at temperature 398 ± 5 K, W/(m · K), at most	0.063	0.067	0.064

The quality of the mineral wool obtained meets the technical specifications for mineral wool. Distinguishing properties of the fiber are high acidity, water resistance and fiber length. Thus, the present investigations of wastes from electricity production with different chemical and mineralogical composition established that they can be used to manufacture mineral fibers. Ashes with high acidity modulus hold promise for the production of fibers with high chemical stability and performance provided that the conditions for obtaining homogeneous melt with high chemical uniformity is obtained, which is possible to accomplish with a plasma setup.

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